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GLACIATION OF THE ALASKA RANGE[1]

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CONTENTS

GENERAL DESCRIPTION

The Alaska Range is the great crescentic belt of mountains in south-central Alaska that in general forms the divide between the streams which drain southward to the Pacific Ocean and those

[1] Published by permission of the Director of the U.S. Geological Survey.

which join Kuskokwim and Yukon rivers to empty into Bering Sea. The name has commonly been used to include the mountains between the headwaters of Skwentna River and Mentasta Pass, but at its southern end the range is not sharply separated from the Chigmit Mountains of the Alaska Peninsula, although the constituent rocks of the two mountain masses are different and their axes, while parallel, do not coincide. At its east end the Alaska Range is directly continuous with the Nutzotin Mountains. The following descriptions are confined to that portion of the range which lies between meridians 144 and 153 west longitude. Considered as a whole, the Alaska Range is a rugged mountain belt broken by but a few widely separated passes. In the region near the head of the Skwentna three breaks in the range are known which may be crossed by pack animals to the Kuskokwim basin. North of these passes the range becomes of impressive height and ruggedness, culminating in two great peaks, Mount Foraker and Mount McKinley, with elevations of 17,000 and 20,300 feet respectively. Northeast of Mount McKinley the range decreases in height, and at the head of certain tributaries of Chulitna River is broken by one or two passes. East of Nenana River the range once more becomes rugged, the loftier peaks averaging about 8,000 feet in height, although Mount Hayes reaches an elevation of over 13,700 feet. Delta River crosses the range in a low pass, east of which the highest peaks are from 8,000 to 10,000 feet in elevation.

HISTORY OF EXPLORATION

The first white man to cross the Alaska Range was Lieutenant Henry T. Allen, who discovered Mentasta Pass in 1885. West of this pass the mountains were unexplored until 1898, when J. E. Spurr[1] crossed from the Skwentna basin to the Kuskokwim, Eldridge[2] ascended the Susitna and crossed Broad Pass to Nenana River, and Mendenhall,[3] attached to an army exploratory party

[1] J. E. Spurr, "A Reconnaissance in Southwestern Alaska, in 1898," *Twentieth Ann. Rept. U.S. Geol. Survey*, Pt. 7, 1900, pp. 31–264.

[2] G. H. Eldridge, "A Reconnaissance in the Susitna Basin and Adjacent Territory, Alaska, in 1898," *ibid.*, pp. 1–30.

[3] W. C. Mendenhall, "A Reconnaissance from Resurrection Bay to the Tanana River, Alaska," *ibid.*, pp. 271–340.

under Captain E. F. Glenn, crossed Delta Pass. Since that year geologic and topographic surveys have gradually been extended until only small portions of the range are now unknown. Captain Herron, in 1899, discovered Simpson Pass at the head of Kichitna River, and explored a portion of the Kuskokwim lowland. In 1902 Brooks and Prindle[1] traversed the range at Rainy Pass and followed the north slope of the mountains between Kuskokwim and Nenana rivers, and in the same year a topographic and geologic map[2] was made of the south slope between Delta and Mentasta passes. In 1903 Dr. F. A. Cook organized a party for the ascent of Mount McKinley from the northwest. The route already established by Brooks and Prindle from Tyonek to the head of the Skwentna, and thence along the northwest base of the mountains, was followed as far as Muldrow Glacier. From that point the party proceeded in an eastward direction, discovered a pass across a glacier, and emerged on the headwaters of Chulitna River. In 1906 a topographic map was made by R. W. Porter of a portion of the northwest border of Susitna basin.[3] In 1910 the area on the north of the range between Nenana and Delta rivers was mapped[4] geologically and topographically, as was a portion of the range south of this,[5] and during that same summer some explorations were carried on in the high range southeast of Mount McKinley by a party under the leadership of Herschel Parker and Belmore Brown. In 1911 a portion of the northwest border of the Susitna basin was visited by the writer.[6] This gradual completion of reconnaissance surveys has added to our knowledge of the geography of the region until the time seems ripe to summarize briefly the facts with regard

[1] A. H. Brooks and L. M. Prindle, "The Mt. McKinley Region, Alaska," *Prof. Paper U.S. Geol. Survey No. 70*, 1911.

[2] W. C. Mendenhall, "Geology of the Central Copper River Region, Alaska," *Prof. Paper U.S. Geol. Survey No. 41*, 1906.

[3] Published in "The Mt. McKinley Region, Alaska," *Prof. Paper U.S. Geol. Survey No. 70*, 1911.

[4] S. R. Capps, "The Bonnifield Region, Alaska," *Bull. U.S. Geol. Survey No. 501*, 1912.

[5] F. H. Moffit, "Headwater Regions of Gulkana and Susitna Rivers, Alaska," *Bull. U.S. Geol. Survey No. 498*, 1912.

[6] "The Yentna Region, Alaska," *Bull. U.S. Geol. Survey*. In preparation.

to the past and present glaciation of the range as observed by the several geologists who have worked in this field. Such a summarization must naturally be incomplete until the range has been fully mapped.

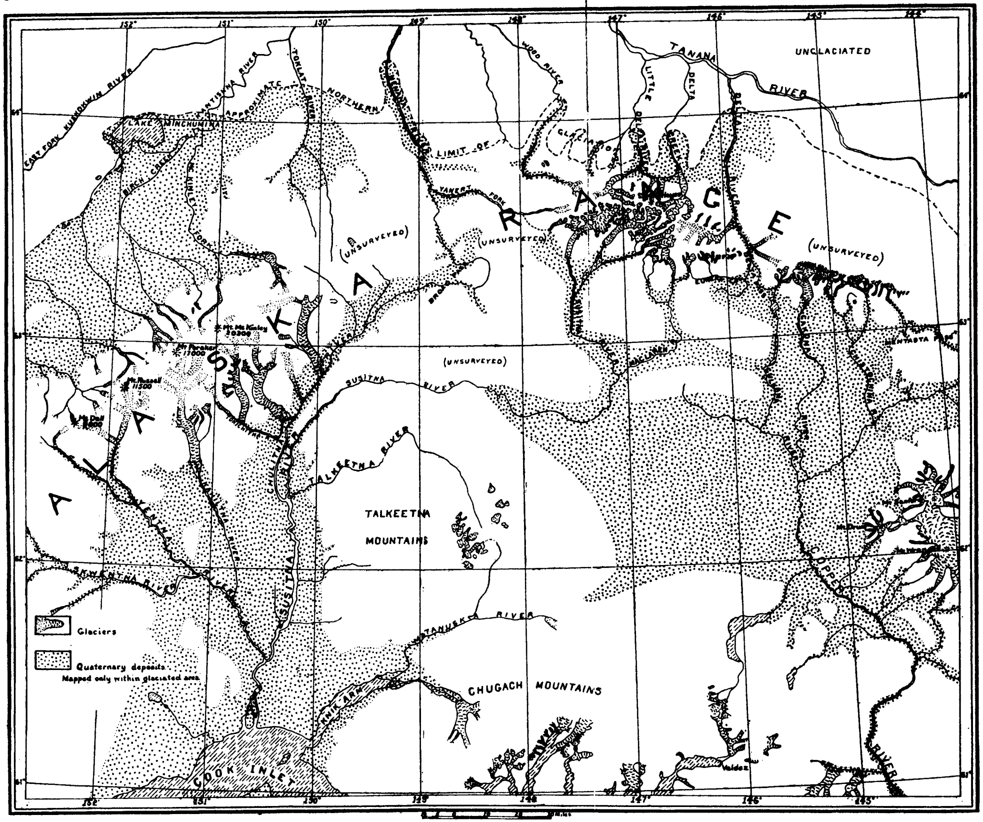
DISTRIBUTION OF EXISTING GLACIERS

The distribution of existing glaciers in the surveyed areas is shown in the accompanying map, Plate I. In many cases the upper ends of the glaciers lie in unexplored and unmapped portions of the mountains and in these places the probable headward extensions of the glaciers are indicated by a different pattern. The shapes of the unmapped portions will be modified when more exact information is obtainable, but their general position is believed to be approximately as indicated.

As is to be expected, the glaciers reach the greatest size and are most closely spaced in the higher portions of the range, and are smaller, or are wanting altogether in the regions of lower relief. They are all, however, distinctly of the valley-glacier type, and differ in this respect from the glaciers of lower Kenai Peninsula, the Wrangell Mountains, and the coastal range west of Mount St. Elias, which originate in the ice caps and spread from these down the valleys. No extensive ice caps exist in the Alaska Range and each glacier is fed from ice which accumulates in its own basin.

By far the largest glaciers of the range are those of the group which drains from the northwest into the Susitna basin. These head on the slopes of the highest mountains of North America, and by their presence so obstruct the approaches to the crest of the range that an area of several thousand square miles exists which has never been penetrated by man. This group doubtless includes large ice tongues which lie in the unsurveyed area east of Mount McKinley, and are, therefore, not shown on Plate I.

The next important group of glaciers is that which occupies the range for about 50 miles west of Delta River, and which includes many large and vigorous ice streams which do not, however, equal in length or area those in the vicinity of Mounts McKinley and Foraker. The third group lies east of Delta River and the glaciers become smaller and disappear as Mentasta Pass is approached.



MAP OF THE ALASKA RANGE, ALASKA

The existing glaciers are shown by the conventional symbol. The dotted areas show the distribution of the Quaternary deposits within the glaciated area. The line of dashes indicates approximately the northern limit to which the earlier glaciers reached. Compiled from published and unpublished maps of the U.S. Geological Survey.

The north side of the range is here unsurveyed, but it is reported that the glaciation is less extensive on that side than on the south. The glacial conditions east of the pass and on the north side of the Wrangell Mountains have already been briefly described.[1]

One of the most striking features of the map (Plate I) is the great development of the glaciers on the southward slope of the range as compared with those on the north slope, especially in the vicinity of Mount McKinley. Two factors are believed to be responsible for this unequal distribution of glacial ice. Probably the most important of these is the greater amount of precipitation on the south slope. The moisture-laden winds from the Pacific in passing northward over the range drop most of their content as snow on the south slope. On the interior slope the precipitation is light, and as the amount of snowfall has a controlling influence in the growth and continued activity of glaciers, the southward-moving ice tongues have a great advantage over the poorly fed glaciers on the north. The second factor which favors the Pacific slope glaciers is the greater area of their accumulating grounds. On the south slope the average distance from the crest line to the base of the main range is more than 25 miles, while on the north it is only half this distance. The area of accumulation of those on the north slope is therefore much more restricted and the glaciers are correspondingly of smaller proportion. This unequal development of glaciers holds in other parts of the range as well, in the vicinity of Mount Hayes, and east of Delta River, in regions where there is not the same discrepancy in the area of the collecting fields. The advantage is here given to the southward-moving glaciers by the greater snowfall on that side of the range.

INFLUENCE OF GLACIERS ON THEIR VALLEYS

The erosional effects of glaciers upon their valleys have been so frequently and so fully discussed by many writers that it is unnecessary to dwell upon them here in detail. The most noticeable results of this erosion are the development of the great U-shaped troughs, with the removal of the minor irregularities seen

[1] S. R. Capps, "Glaciation on the North Side of the Wrangell Mountains, Alaska," *Jour. Geol.*, XVIII (1910), 33–57.

in stream-developed valleys, and the truncation of the lateral spurs, giving straight-walled rock troughs. Where the valley makes a bend in its course the ice erosion has developed great sweeping curves so that the glaciers seldom bend at sharp angles. These topographic features, with hanging tributary valleys and a large number of other characteristic and readily recognizable phenomena of glacial erosion, are of service in determining the thickness and former extent of the glaciers in those places where deposits of glacial débris are not to be found.

EVIDENCE OF EARLIER AND MORE EXTENSIVE GLACIERS

The outer limits to which the glaciers of the Alaska Range reached at the time of their maximum extent have for the most part not yet been determined, and much careful detailed work will be required before this limit can be accurately marked. There are certain facts available, however, which show in a general way the area covered by the ice during its greatest development. On the south side of the range no limit of glaciation is shown on the accompanying map (Plate I), for all of the area here shown except the higher peaks and ridges of the more important mountain ranges was covered by glacial ice. The entire Copper River basin was occupied by a great glacier, as has been recognized from abundant deposits of glacial till, which are found throughout the basin at points as far as possible removed from the mountains in which the ice must have originated. The Copper River ice sheet was of great thickness, for it escaped from the basin in a number of directions. It certainly pushed north across Delta Pass, and probably also to the northeast through Mentasta Pass.

To the west it extended into the head of Susitna basin, as is shown by the widely distributed deposits of glacial till in that region. Matunaska Valley heads in a broad divide at an elevation of 3,000 feet, and probably furnished an outlet for the glacial ice to the southwest. The present drainage outlet of the basin, through the Copper River Valley, was also an outlet for a part of the glacial ice, although it is probable that this outlet was not the course followed by the pre-glacial streams and that it was not established till Glacial times. Near the mouth of Chitina River

glacial erratics and glacially sculptured mountain tops show that the great Copper River Glacier at that point overrode mountains 5,690 feet in height. The bed of the glacial valley is here about 500 feet above sea-level so that the glacial ice must at one time have been at least a mile in thickness.[1]

The Susitna Basin Glacier to the westward was continuous with that in the Copper River basin and was of a similar order of magnitude. It filled the broad Susitna lowland and extended southward down the Cook Inlet depression. It may even have reached to the mouth of the inlet, though this has not yet been determined. Some idea of the thickness of this ice sheet may be gained from the fact that north of the mouth of Skwentna River the Yenlo Hills, an isolated group of hills which lie more than 20 miles from the Alaska Range, show glacial erosion and have foreign erratic bowlders at an elevation of 3,300 feet above sea-level, and the ice probably stood several hundred feet higher than the point at which the erratics were found. Along the flanks of the main range there is evidence that the ice surface reaches elevations of over 4,000 feet. The conclusion, therefore, seems unavoidable that at the time of greatest ice accumulation all of the area between the crescent of the Alaska Range and the Pacific Ocean was so covered with glacial ice that only the higher peaks and ridges of the range, and of Talkeetna, Chugach, Kenai, and Wrangell Mountains projected above its surface. It must be remembered, however, that these basins were most favorably situated for large glaciers to accumulate, for they were surrounded on all sides by high mountains from which a multitude of valley glaciers descended to the lowlands. Only a part of the ice originated in the Alaska Range to the north and west.

The restricted development of the earlier glaciers on the interior slope of the Alaska Range as compared with those on the south and east slope is even more striking than the difference which exists between the present-day glaciers on the opposite sides of the range. In considering the northern limit of glaciation as shown on the map (Plate I) it is necessary to have in mind the fact that much of this region is still unsurveyed and that the writer intends to show only in a very general way the borders of the area which the

[1] F. H. Moffit, oral communication.

ice covered. The region north and west of Mount McKinley has been visited by but one surveying party, whose route, however, lay close to the mountains, well within the glaciated area. Brooks[1] states that "the position of the northern front of the ice in the Kuskokwim basin has not been determined but there is reason to believe that it extended as far as Lake Minchumina, or about 30 miles beyond the mountain front." The area between Nenana and Delta rivers was studied by the writer in 1910,[2] and it is believed that the northern limit of glaciation as shown on the map for that region is not greatly in error. The country east of Delta River is still unsurveyed and the ice limit as shown is believed to be only an approximation. It is probable that the same factors which are responsible for the difference in area of glacial ice on opposite sides of the range today and which have already been discussed were operative at the time of the great ice advance, and explain the lesser development of the northward-moving glaciers at that time.

EXISTING GLACIERS

It is not the purpose of this paper to give a detailed description of the multitude of glaciers of the Alaska Range, and such a task would be impossible in the present state of our knowledge of them. Brief descriptions of a few of the more important glaciers which have been observed will, however, be given, especially those which have been visited by the writer in person, and such facts as have a bearing on the recent history of the glaciers, whether they seem to be advancing or retreating, will be recorded.

SUSITNA BASIN

SKWENTNA DRAINAGE

Skwentna River has a number of glaciers at the heads of its various tributaries, but many of them lie in unmapped territory and most of them are not of large size. They are sufficiently numerous and active, however, to keep the river in a turbid state during

[1] A. H. Brooks, "The Mt. McKinley Region, Alaska," *Prof. Paper U.S. Geol. Survey No. 70*, 1911, p. 126.

[2] S. R. Capps, "The Bonnifield Region, Alaska," *Bull. U.S. Geol. Survey No. 501*, 1912.

the summer, and to cause it to build extensive gravel flats in favorable portions of its course.

YENTNA DRAINAGE

Both forks of Yentna River are known to rise in glaciers, those on the west fork being of comparatively small size. The East Fork has its source in two large ice tongues, one of which probably heads on the slopes of Mount Dall, and flows eastward, and the other apparently drains the ice from the southern flank of Mount Russell, and moves in a southward direction. The two tongues meet at their distal ends at an elevation of about 400 feet above sea-level. As seen from a distance, both of these glaciers seem to be relatively free from morainal covering at their lower ends, though they are striped with longitudinal surface moraines. It is not known whether they are advancing or retreating as they have not been critically observed.

Glacio-fluvial deposits and moraines.—The forks of Yentna River both show the characteristic features of glacial streams above their junction, having wide, bare flood plains of sand and gravel, over which the stream flows in an intricate network of braided channels. Below their junction the stream maintains a much more definite channel to its mouth. The valley floor throughout its length, however, is covered with a heavy deposit of glacial outwash, and bed rock outcrops along the banks at only a few places. Some recognizable terminal moraine occurs between the forks for a few miles above their junction, but such deposits are not common. Extensive terraces are developed from the earlier outwash gravels and border the present stream flat in its lower course and are of wide extent between lower Skwentna River and the Yentna (Plate I).

Kahiltna Valley.—Kahiltna River, a tributary of the Yentna, some 25 miles above its mouth, heads in one of the largest glaciers of the Alaska Range. This glacier, which terminates 600 feet above sea-level, has pushed to the edge of the mountains and is expanded somewhat in its lower end into a piedmont lobe which is four miles wide at its face. For the lower 13 miles of its length this ice tongue averages 3 miles in width, has a smooth, even gradient, and is little broken by crevasses except near the edges (Fig. 1). The surface is

unusually free from moraine except for a zone along either side, and white ice shows all the way to the lower end. From favorably situated points along its sides the lower 20 miles of the glacier may be seen, but above this a bend in the valley cuts off the view. A number of tributary ice streams may be seen joining the main glacier from either side. Above the bend the extent of the Kahiltna Glacier is not known, but the great size of the lower portion indicates that the supply basin must be large. It doubtless extends to the crest of the range, and probably includes the southern slopes of Mount Foraker. In all, this glacier is probably at least 35 miles long, and its area, including the many headward tributaries, must be well over 100 square miles.

An examination of the lower end of Kahiltna Glacier shows that the edge has probably been about stationary for a long time. There are no important recessional moraines to be seen, and spruce trees many inches in diameter grow close to the glacier front. The ice edge must, therefore, be as advanced as at any time for at least one hundred years.

A number of streams which themselves head in glaciers enter Kahiltna Valley from the east above the terminus of the glacier, the waters disappearing beneath the ice, or joining the marginal streams. Among these separate, smaller ice fields are the unusually beautiful ones at the heads of Granite and Hidden creeks (Fig. 2).

Glacio-fluvial deposits and moraines: Below Kahiltna Glacier the stream flat shows a bare expanse of gravel bars nearly 4 miles wide at the glacier, and the turbulent river flows across this aggrading flood plain in a complex of constantly shifting channels. The materials are coarsest near the glacier, and become progressively finer down stream. As the distance from the ice front increases the width of the bare flat is diminished by the encroachment of spruce timber and shrubs from either side. About 17 miles from its source the stream gathers into a single channel and enters a postglacial gorge to which it is confined for much of the remainder of its course to the Yentna. Glacio-fluvial terraces are not conspicuously developed along the Kahiltna, but the interstream areas bordering the river are covered by a coating of glacial till and morainic material of varying thickness (Plate I).

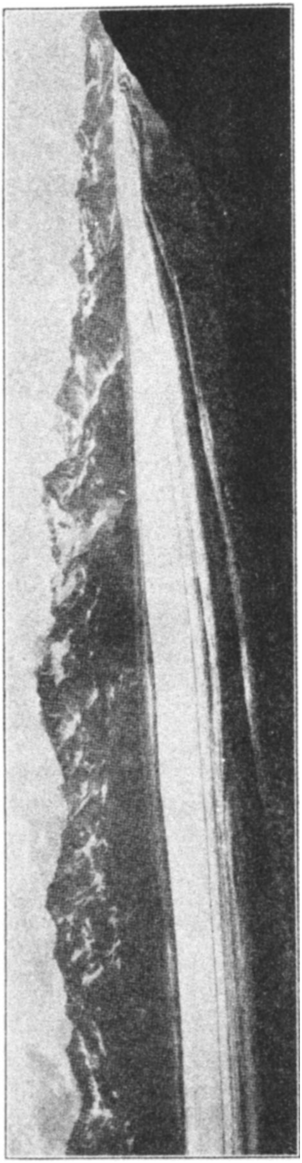


FIG. 1.—View across Kahiltna Glacier from a point 7 miles above the terminus. The glacier is here three miles wide, 1911

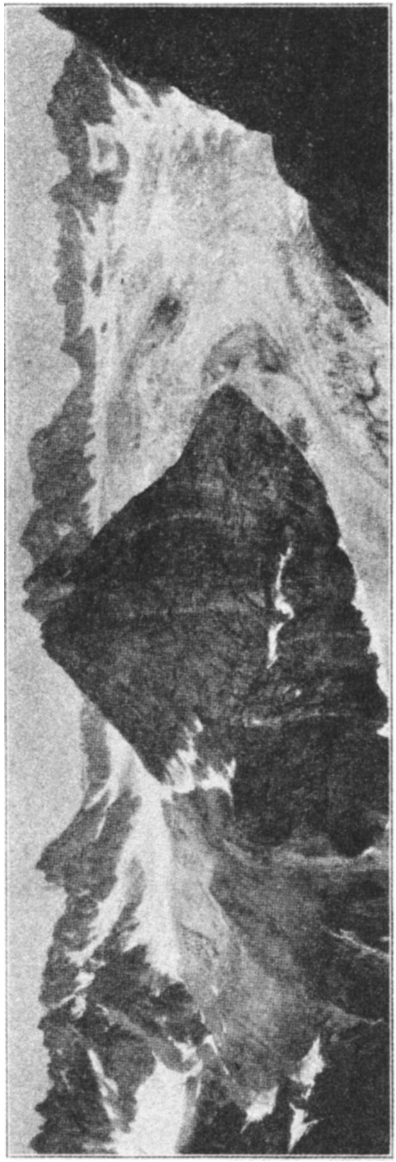


FIG. 2.—Cascading glaciers at the head of Hidden Creek, 1911

CHULITNA RIVER DRAINAGE

Tokichitna Valley.—Tokichitna River, a tributary of the Chulitna, receives the discharge from two very large and one medium-sized glacier. The smallest of the three, at the head of the valley, is known as Little Tokichitna Glacier. In its lower part it is nearly a mile wide, and although most of its basin is unsurveyed the glacier has probably a length of at least 10 miles. For several miles above its terminus the surface of this glacier is so covered by moraine that no ice is visible, except along the lower edge where

FIG. 3.—Glacier at the head of Granite Creek, and the rugged mountains between Kahiltna and Tokichitna glaciers.

stream cutting is active. This ice tongue also differs from most valley glaciers in that its sides are not steep, and separated from the valley walls by a depression, even at its lower end. The sides fit flush against the rock valley walls, and detritus from the walls and from steep tributary gulches moves directly out upon the surface of the glacier (Fig. 4). The terminal moraine has been removed almost as rapidly as deposited, and accumulations at the glacier end are small. Trees of considerable size grow only a few hundred feet in front of the ice foot, and directly in its path, so that the glacier cannot have retreated far for a long period of years, or if it has, it has readvanced an equal distance.

Tokichitna Glacier, the principal source of Tokichitna River, joins the east-west valley of that stream from the north, $3\frac{1}{2}$ miles below the end of Little Tokichitna Glacier. It is one of the four largest glaciers of the range, and the borders of the lower 20 miles of the main lobe have been mapped. For this distance the ice stream averages nearly 2 miles in width, with a maximum width of over $2\frac{1}{2}$ miles. The upper unexplored portion lies among the high, rugged peaks of the range, and probably heads on the slopes of Mounts McKinley and Hunter. The total length must be nearly 30 miles.

FIG. 4.—The moraine-covered lower portion of Little Tokichitna Glacier, 1911

The lower end is moraine covered for several miles above the terminus, but above the first bend white ice appears. A heavy growth of spruce timber, close to the front edge of the glacier, shows that the ice edge is now as far advanced as it has been for a long time, and probably indicates a state of equilibrium between supply and wasting.

Near the mouth of Tokichitna River a third, very large glacier pushes out from the mountains from the northwest and spreads out into a bulb-shaped piedmont lobe over 4 miles wide. It is known as either Mud or Ruth[1] Glacier, the former being the name most generally used by the miners of the district, and said to have

[1] F. A. Cook, *To the Top of the Continent.* Doubleday, Page & Co., 1908, p. 90.

been given because of the dirty, moraine-covered character of the terminus.

The lower 16 miles of the glacier, which have been mapped show an average width of nearly 3 miles. In this section the the glacier makes a great bend, and the direction of movement in the principal headward tributary is from north to south.

Glacio-fluvial deposits: None of the large glaciers of the Tokichitna basin have left conspicuous terminal moraines, and this is a result of the topographic position of the glacier ends, situated as they are in confined valleys where the glacial waters are given abundant opportunity to remove the glacial débris as it is dropped by the ice. There are, however, extensive deposits of stream-laid glacial outwash, for although the streams are of large volume they are overloaded, and the aggradation of the valley floor is rapid. Tokichitna River resembles the other glacial streams already described in the development of its aggrading flat, and in the way in which it splits up into many branching channels.

Main Chulitna Valley.—Chulitna River is known to receive drainage from several small and one large glacier from the northwest, above the Tokichitna. The large ice stream, named Fidèle Glacier by Cook,[1] who has published the only description of it, is described by him in the following terms:

> The glacier starts from the northeast ridge of Mount McKinley and flows almost due east for fifteen miles, where it receives a large arm from the north. Five miles southeast of this another arm swells the bulk of the great icy stream, and then it takes a circular course, swinging toward the Chulitna. Its face is about seven miles wide, its length is about forty miles, and the lower ten miles are so thoroughly weighted down by broken stone . . . . that no ice is visible.

Northwest of this glacier there is a stretch of nearly 70 miles of mountains which are almost all unsurveyed, and about the glaciation of which little is known.

HEAD OF SUSITNA RIVER

The headwaters of the main fork of Susitna River, and its tributary the Maclaren, were surveyed in 1910. In the high mountains of this area the glaciers are closely spaced and fill the

[1] F. A. Cook, *op. cit.*, pp. 90–91.

headward ends of all the important valleys (see Plate I). In describing these glaciers Moffit[1] says:

> The most conspicuous of these glaciers are Gulkana Glacier, the glacier in which Eureka Creek and East Fork of Maclaren River head, Maclaren Glacier, and the two large glaciers at the head of Susitna River. The last two are much larger than any others in this region. They are fed by the snow fields in the high rugged country south of Mount Hayes and Cathedral Mountain and are the principal sources of the Susitna, although the glaciers to the east also contribute much water. The westernmost of the two large glaciers is about 25 miles long and more than $1\frac{1}{2}$ miles wide throughout its whole length. The eastern glacier is about 2 miles wide, but is not so long as the first. Maclaren River Glacier is much smaller than either of these, being a little more than 10 miles long and not more than a mile wide at its lower end. Gulkana Glacier and Cantwell Glacier (10 miles northwest of the westernmost Susitna Glacier) are remarkable . . . . in that they contribute water to both Bering Sea and Pacific Ocean drainage.
>
> Most of these glaciers appear to be retreating. Their surfaces are smooth, they end in smooth slopes rather than ice cliffs, and most of them show by the position of terminal moraines that they have receded considerably in recent times.

The peculiar drainage mentioned by Moffit deserves a further word of description. Three glaciers on the south side of the range, namely, Cantwell Glacier, the glacier at the head of Eureka Creek, and that one in which Gulkana River heads, all contribute water to two separate great drainage basins. The obvious outlet for the waters from all these glaciers is to the south, for the distance to the sea is shortest in that direction, and a high mountain range must be crossed by any northward-flowing streams. No detailed studies have been made at any of these places, but in each of the three cases the controlling conditions were probably much the same. The greater accumulation of glaciers on the south side of the range, at the time of the maximum glaciation, filled both Copper River and Susitna basins with ice to a great thickness, as has already been stated. This ice body found such outlets as were available and at least two tongues pushed northward across the Alaska Range through what are now Broad and Delta passes. These outlets of escape were probably determined by low divides created by the

[1] F. H. Moffit, "Headwater Regions of Gulkana and Susitna Rivers, Alaska," *Bull. U.S. Geol. Survey No. 498*, 1912, p. 53.

preglacial streams. Both passes were scoured deeply by glacial erosion, and when the ice retreated the low gaps were left. We do not know whether the early postglacial drainage followed the present lines or not, but as the valleys were gradually filled with glacial outwash gravels the streams flowed sometimes in one direction, sometimes in the other. Gulkana Glacier, in the fall of 1910, was observed to send most of its water into the Delta River drainage, although a small stream flowed to the Gulkana. The constant shifting of channels which takes place doubtless gives the Gulkana the greater portion of water in some years.

COPPER RIVER BASIN

Between Delta and Mentasta passes there is a large number of glaciers draining by various tributary streams into Copper River. As the mountains are here all less than 10,000 feet in elevation, the glaciers are in general smaller than those of the higher mountains west of the Delta. Mendenhall, who visited these glaciers in 1902, says:[1]

> The most conspicuous of them is the one in which Gakona River rises (Fig. 7). It is perhaps 12 miles long and expands near its foot to a width of 3 miles. This lower portion is a rough, pinnacled mass of ice which rises several hundred feet above the valley floor on either side, and is visible for many miles in either direction.
>
> Chistochina Glacier fills the greater part of the narrow piedmont valley north of Slate Creek and the upper Chisna. It flows east and west into branches of Chistochina River, and receives as tributaries a number of smaller glaciers which flow down from the crest of the range.

Mendenhall fails to state whether the glaciers at the time of his visit gave evidence of recent retreat or advance.

GLACIO-FLUVIAL DEPOSITS AND MORAINES

Great areas in the Copper River basin are covered with deposits which are directly or indirectly of glacial origin. In the interstream areas these beds are composed largely of glacial till. Along the stream courses there are extensive deposits of glacial outwash gravels. Their distribution is shown on Plate I.

[1] W. C. Mendenhall, "Geology of the Central Copper River Region, Alaska," *Prof. Paper U.S. Geol. Survey No. 41*, 1905, p. 89.

FIG. 5.—Panorama of a part of Gulkana Glacier. Photograph by F. H. Moffit, 1910

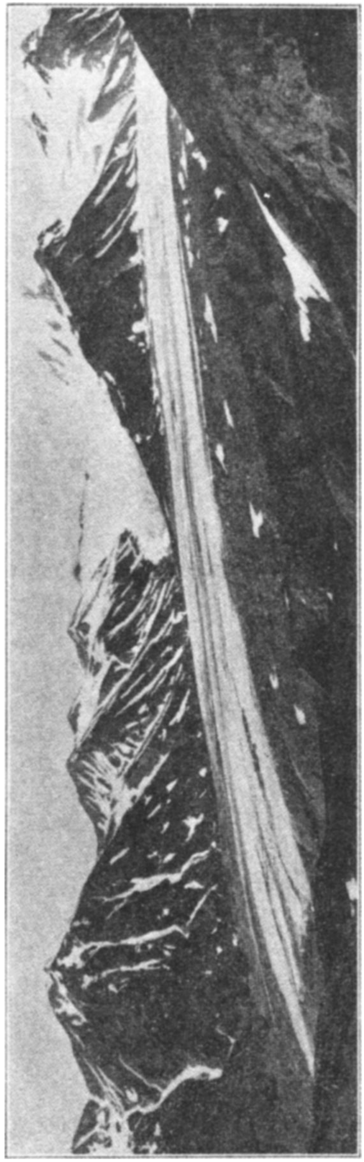


FIG. 6.—Lower end of Gulkana Glacier. This glacier sends a part of its drainage to the Pacific Ocean by way of Gulkana and Copper rivers, and the rest to Bering Sea through Delta, Tanana, and Yukon rivers. Photograph by F. H. Moffit, 1910.

TANANA AND KUSKOKWIM BASINS

The Tanana slope of the Alaska Range, between Mentasta Pass and Delta River Valley, is unsurveyed, and little is known of the glaciers there beyond the fact that as seen from Tanana River there appears to be no great development of snow fields in these mountains, and it is likely that the glaciers are smaller than on the south slope, as in other parts of the range.

FIG. 7.—Gakona Glacier from below. The vegetation-covered terminal moraine indicates that the glacier is in a state of retreat. Photograph by W. C. Mendenhall, 1902.

DELTA RIVER DRAINAGE

Two large ice tongues push down toward Delta River from the east and furnish a considerable part of its waters. The uppermost of them, known as Canwell Glacier, heads opposite to Gulkana Glacier. Its upper basin is unsurveyed. The terminus pushes down to within two miles of the Delta and is heavily moraine covered. A short distance north of it another, Castner Glacier, terminates at the edge of the Delta Valley. Its front is somewhat expanded forming a bulb-

shaped lobe, and is covered with morainal material upon which alder brush and other bushes have established themselves. Its melting waters emerge as a large stream from beneath the ice (Fig. 8).

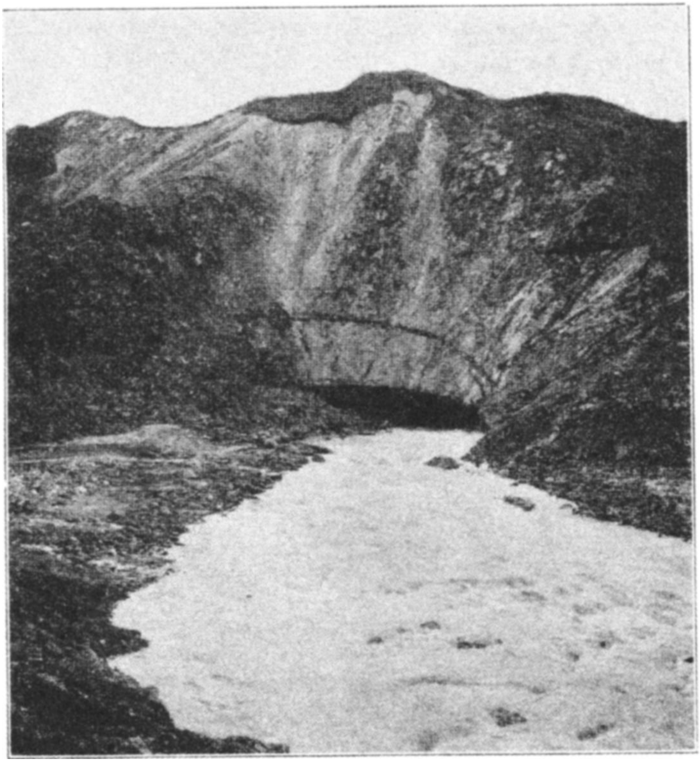


FIG. 8.—The emergence of a glacial stream from beneath Castner Glacier, 1910

West of Delta River the mountains are higher and the glaciers of larger size. One large unnamed glacier emerges from the central part of the range and terminates on the banks of Delta River. It is known to have a length of more than 20 miles, and averages more than a mile in width. Its terminal end is heavily covered with débris, and terminal moraine deposits indicate that the glacier is retreating.

DELTA CREEK DRAINAGE

Delta Creek drains a part of the high group of mountains in the vicinity of Mount Hayes and heads in two important glaciers.

That one which gives rise to the main fork of the stream is 17 miles long and in places is two miles wide (Fig. 9). The lower end is moraine covered for several miles and gives evidence that it is probably in a state of retreat. East Fork of Delta Creek has its source in a glacier which descends from the slopes of Mount Hayes. While most of its waters are tributary to Delta Creek, a small lobe drains northwest to Little Delta River.

LITTLE DELTA RIVER DRAINAGE

East Fork of Little Delta River rises in the third large northward-flowing glacier from the mountains about Mount Hayes and Cathedral Mountain (Fig. 10). Some of its headward tributaries

FIG. 9.—Delta Creek Glacier. The high peak at the right is Mount Hayes. 1910

lie in unexplored territory, but the glacier is known to be more than 15 miles long and its main lobe is over $1\frac{1}{2}$ miles wide. The foot is moraine covered and ends in a thin edge. Outstanding moraine ridges show the glacier to be retreating.

OTHER GLACIERS IN UNSURVEYED AREAS

To the west of the East Fork of Little Delta River there are a number of streams, notably West Fork of Little Delta River, Wood River, Yanert Fork of Nenana River, and Toklat River which head in unsurveyed areas, but which are known from the character of their waters and from the reports of prospectors to head in glaciers. In most of this region the mountains are lower than to either the east or the west, and it is probable that the glaciers are of comparatively small size.

KANTISHNA AND KUSKOKWIM DRAINAGE

The glaciers on the northwest slope of the range, in its highest part, drain either by Kantishna River to the Tanana or into the Kuskokwim. Only a narrow belt along the base of the mountains has been surveyed and information concerning the glaciers is meager. Of them Brooks[1] says:

All the largest northward-flowing glaciers of the Alaska Range rise on the slopes of Mount McKinley and Mount Foraker. Of these the largest are the Herron, having its source in the neve fields of Mount Foraker; the Peters, which encircles the northwest end of Mount McKinley, and the Muldrow, whose front is about 15 miles northeast of Mount McKinley, and whose source

FIG. 10.—Glacier at the head of East Fork of Little Delta River. The high peak in the center is Cathedral Mountain. Photograph by J. W. Bagley, 1910.

is in the unsurveyed heart of the range. The fronts of all these glaciers for a distance of one-fourth to one-half a mile are deeply buried in rock débris.

Along the crest line there are numerous smaller glaciers, including many of the hanging type. Both slopes of Mount McKinley and Mount Foraker are ice covered. . . . . The glaciers that came under the observation of the writer all appeared to be receding rapidly. There is, however, little proof of the rate of recession. Spruce trees about 6 inches in diameter were seen in the old path of the Muldrow Glacier about 5 miles from the present ice front. If the age of these trees is estimated at fifty years, this fact, so far as it goes, indicates an average annual recession of about one-tenth of a mile.

QUATERNARY DEPOSITS IN THE TANANA AND KUSKOKWIM BASINS

Since the higher mountains are still in the glacial period, and since moraines and outwash materials are now being, and have

[1] A. H. Brooks, "The Mt. McKinley Region, Alaska," *Prof. Paper U.S. Geol. Survey No. 70*, 1911, pp. 125–26.

been continuously deposited since Pleistocene times, it is impossible to make a sharp separation between the deposits which are directly or indirectly of glacial origin, and those which are now being formed by the streams. Glacial waters form such an important element in the drainage of both Kuskokwim and Tanana rivers that all the deposits of these two great rivers might be considered to be of glacio-fluvial origin. On the accompanying map (Plate I) all the Quaternary deposits, including morainal material, glacial outwash, terrace gravels, and the present stream deposits, are mapped in a single pattern, and are indicated only within the area which is believed to have been covered by glacial ice. Beyond the northern limit of glaciation, as mapped, the broad lowlands of both Tanana and Kuskokwim rivers are covered with Quaternary deposits which probably attain great thickness. It should be remembered that northwest of Mount McKinley the line along which the northern limit of glaciation is mapped, and much of the area shown as covered with Quaternary deposits, has not been critically studied, and the mapping as given here has only a tentative value.

SUMMARY

The higher portions of the Alaska Range are still in the glacial period, the difference between the present glaciation and the former more extensive glaciation being one of degree and not of kind. The present mountain glaciers are all of the valley-glacier type, no large, unbroken ice caps being known. Even at the time of the maximum glaciation the higher peaks and ridges probably projected above the ice mass, and the mountain glaciers even then were valley glaciers. In earlier times the glaciers protruded from their mountain valleys and coalesced into piedmont glaciers. On the south side of the range these attained great size, filling both Copper and Susitna basins and extending southward along the valleys of these rivers to the Pacific Ocean, and having a thickness measured in thousands of feet. Ice from these basins pushed northward across the Alaska Range through Delta and Broad passes, and probably also through Mentasta Pass. On the north side of the range the former glaciers were also of much greater

size than the present ones, but the ice fields there were never equally extensive with those on the south. The present distribution of glaciers shows the same contrast between those on opposite sides of the range, but the discrepancy is not so great now as formerly. In the vicinity of Mount Hayes this difference is least well marked, the ice tongues draining to the Tanana being only slightly smaller than those at the head of the Susitna. None of the earlier glaciers north of Mount Hayes reached more than 30 miles farther than the present ice edge, while south of this mountain the glaciers extended more than 200 miles beyond the present terminations. From the facts available in regard to this point, the glaciers of the Alaska Range seem in general to be in a state of retreat. Several large glaciers southeast of Mount McKinley are exceptions to this rule and are either advancing or have remained about stationary for a time sufficiently long to allow good-sized trees to grow in their paths.

The Alaska Range offers a wide range of types and a great number of examples of the many forms of valley glaciers, and offers an attractive and practically untouched field for the student of glacial phenomena.